TROPICAL BROADCASTING

Choice of Frequencies

By T. W. BENNINGTON

The technical problem of providing economical broadcast coverage for wide tropical areas is likely to assume importance after the war, especially with regard to the British Crown Colonies and Protectorates. "Long-short" wavelengths will probably be used for the purpose, and it is concluded here that, considered in the light of present knowledge, the existing channel allocations in these bands are inadequate.

IT has for a long time been recognised that the factors affecting the choice of wavelengths suitable for a local broadcasting service are not the same in tropical as in temperate countries. The medium-wave broadcasting band — whatever may be its deficiencies and drawbacks—still has much to recommend it for local broadcasting in the temperate zones. The ground wave has a *moderately* good range, so that fairly good coverage can be attained for a given power radiated; the noise level is (usually) relatively low so that not too great a field intensity is required to provide a workable signal with a properly designed receiver, and a good number of broadcast channels (perhaps not enough) can be accommodated without leading to complications in receiver design.

In the tropics the situation is radically different, principally because the radio noise intensity is usually so high on the medium waves that an excessively high field strength is necessary to provide a workable signal. Consequently the range for a given radiated power is excessively low, and coverage is therefore very poor. For tropical broadcasting it would appear therefore that the short waves ought to be used, for on these the radio noise intensity is much lower.

Tropical Broadcasting Bands.—These facts were readily recognised at the 1938 Cairo Conference and for local broadcasting in tropical countries the 120-metre (2.3-2.5 Mc/s), 90-metre (3.3-3.5 Mc/s), and 60-metre (4.965-5.5 Mc/s) bands were allocated. Noise on these frequencies is much lower than on the medium-wave band, though of course it is necessary, if good coverage is to be attained, that sky wave, and not ground wave transmission should be effected. The range of the ground wave is even smaller than on the medium waves. That is why different frequencies were allocated to the stations for day and for night working; it was necessary to take account of the diurnal ionosphere variations. But knowledge of the ionosphere was not at a very advanced stage at that time (it can hardly be deemed to be so even now, though much more has been learned) and it may be that, had more been known about the subject, these particular tropical broadcast bands would not have been chosen. It would seem, for example, that, because the sun's rays are stronger in the tropics than in temperate regions, the ionisation of both the refracting and absorbing layers of the ionosphere would be higher. If this is so the use of higher frequencies for local short-wave broadcasting would be not only possible but absolutely necessary, than for a similar *short-wave* service in the temperate zones. Let us therefore consider some of the factors affecting broadcasting in the tropics, and see whether any better results might be achieved if other arrangements were in force.

The Tropical Zone.—Geographically, if not ionospherically, the tropical zone comprises those regions lying between the parallels of latitude 23½ deg. N. and 23½ deg. S. If the ionosphere conditions do not correspond with the geographical ones, then the obvious course would be to define the tropical broadcasting zone as that within which the ionosphere exhibited tropical characteristics. The geographical limits to the zone in which the use of the tropical bands allocated by the Cairo Conference was permitted were, in fact, the parallels of latitude 30 deg. N. and S. But the definition of the "radio tropical zone" is not quite so simple.

Although it is true that the ionosphere will set the high limit to the frequencies of use over a given distance and, to some extent, the lower limit also, still it is largely conditions of temperature and climate that control the noise, at least on the lower frequencies. For the tropics are the breeding ground of the thunderstorms which give rise to noise, and although the noise itself is propagated by way of the ionosphere, the efficiency of such propagation will vary very much with frequency. In fact, it is evident that neither the zones of greatest noise intensity nor the regions of the ionosphere where the ionisation is at a "tropical" level, will correspond exactly with the geographically defined tropical zone. Nevertheless, for the sake of simplicity we may assume that they do, and in that way reduce the matter to a workable basis without committing any very great error.

Within the tropics lie some of the most populous countries of the world, including the following countries of the British Commonwealth: Anglo-Egyptian Sudan, Australia (northern part), British Guiana, British Honduras, British Somaliland, Burma (southern part), India (southern part), Kenya, Malaya, Oceana, Rhodesia (Northern and Southern), Tanganyika, West African Colonies, and West Indies (large part).

When the enormous size of these tropical regions is considered, together with the fact that they are not usually at a very advanced stage of economic development, it is seen that there is an additional reason for the use of short waves for the broadcasting service. If the medium waves

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were used the service areas would —during daylight—be limited by the distance range of the ground wave, and this, even if the noise level were relatively low, would not be great enough economically to serve such large areas, most of which are of an entirely rural character. Far too many stations would be required. By the use of short waves however, the distance range of a station is much enhanced, because the transmission is effected by the sky wave, and therefore the service area—albeit the service given is now of the second grade — is very much larger.

The Main Requirements.—It may be well at this stage to define, in the main, the characteristics of what constitutes a suitable wavelength for local broadcasting in the tropics. The term "local broadcasting" is used in this article in contradistinction to the term "long-distance broadcasting." It means that service is given in an area which stretches *from the transmitter outwards* though the limits of the area may be many hundreds of miles distant.

(1) It must be of so high a frequency that the radio noise intensity is relatively low, and so only a moderate field of intensity is necessary to give a workable signal.

If this entails a frequency on which the ground wave range is so small that the sky wave must be used to give the required coverage—and our previous considerations indicate that it will—then

(2) It must be of high enough frequency at any particular time of day that the ionospheric absorption is not too great; otherwise the distance range will be reduced and the coverage limited.

(3) It must be of low enough frequency at any particular time of day that energy radiated even at the greatest angles to the horizontal will not penetrate the refracting layer of the ionosphere; otherwise there will be an undesirable skip zone.

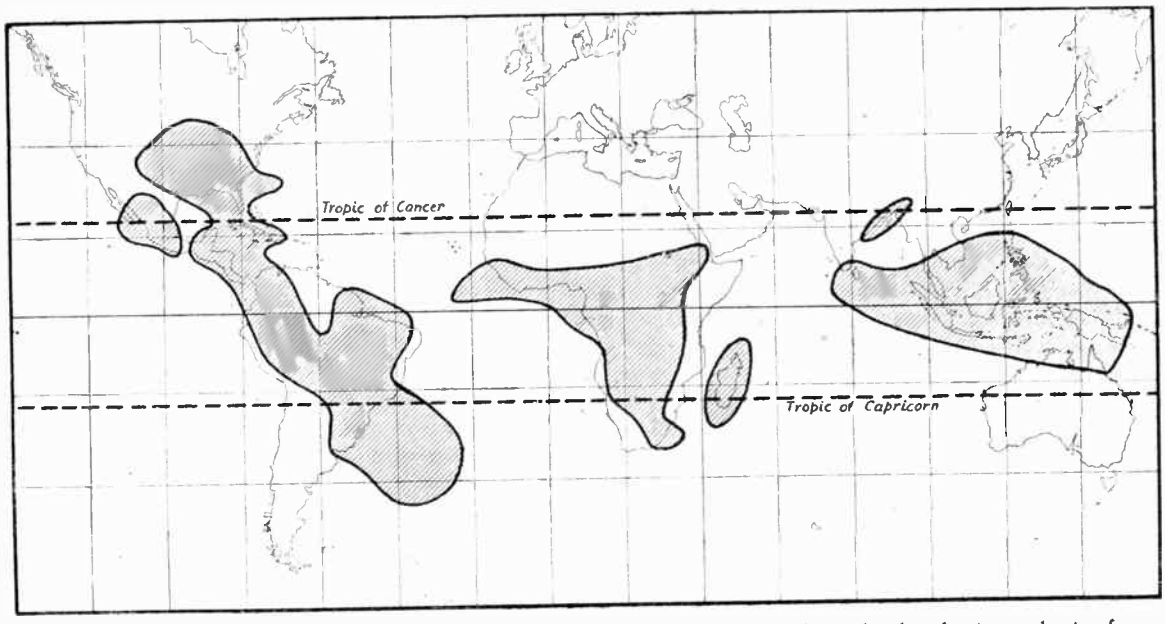
We may now examine the conditions on various frequencies in order to see which of them will best fulfil the above requirements. Let us consider the noise situation first.

As has been mentioned before in these pages,[1] atmospheric noise is caused by the radiation of radio frequency energy by lightning strokes in thunderstorms, and it is in the tropics that these thunderstorms most frequently occur. The noise emanating from the thunderstorms is propagated both as a ground wave and as a sky wave, so that most of the radio noise in temperate zones originates in the thunderstorms of the tropics. Owing to the nature of the current pulses in the lightning strokes more radio energy is radiated at low than at high frequencies, so the noise intensity in the first instance decreases with increasing frequency. Its intensity in any particular geographical zone will, however, vary with frequency in a complex manner—depending not only on the noise intensity produced, but also on the propagation characteristics for the various frequencies.

But so far as the tropics are concerned—at least the land areas within them—we may assume that they are either within the actual thunderstorm-producing areas or so close to them as to be affected mainly by the noise ground waves. This assumption may not be quite true all the year round, since the noise zones move north and south with the seasons, but at least it is justified as showing the worst conditions to be expected.

If we examine the tropical noise intensity on one or two spot frequencies this will give us an idea as to how the noise decreases with

[1] See "Radio Noise" *Wireless World*, Nov. 1944.



Thunderstorm areas of the world, where most of the radio noise is produced (from the thunderstorm charts of Dr. C. E. P. Brooks).

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increasing frequency, and enable us to see which frequency bands are most likely to fulfil requirement (1) above. The measurement of noise presents certain difficulties such that it is found more convenient to measure, not the noise intensity itself but the intensity of a signal which is at a specified level above the noise. In the case of broadcast reception a greater signal-to-noise ratio is necessary than for most other radio services, and in highly developed countries a figure of 40 db. is considered desirable and is in fact generally achieved. However, the minimum requirement for tolerable reception is that the signal field intensity should be 20 db. above that of the noise. Such figures, giving the minimum field intensity necessary to provide a satisfactory signal in the presence of the noise, would be directly to our purpose, but reliable data on this subject applicable to the tropical zone are extremely scanty. However, the following figures are obtained from a careful consideration of what data are available.

Minimum Field Intensity for satisfactory tropical broadcast reception (20 db signal/noise ratio)

1 Mc/s. μV/m	2 Mc/s. μV/m	4 Mc/s. μV/m	8 Mc/s. μV/m
3,600	1,550	570	170

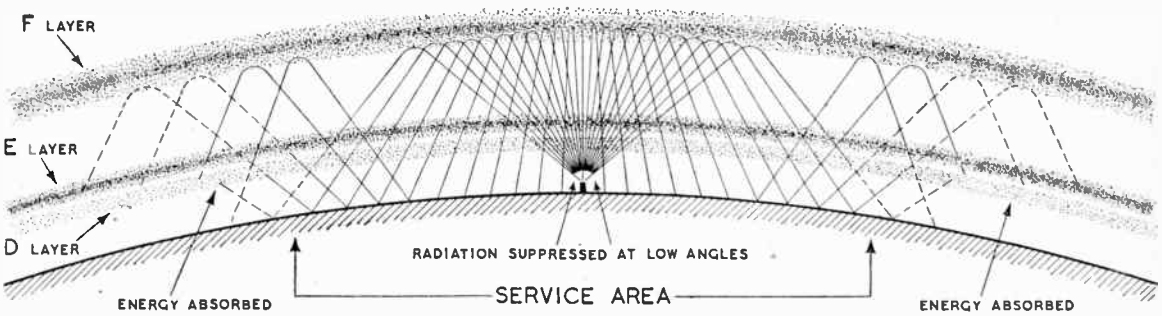
The above figures are indicative of the situation considering the noise alone, at what is, generally speaking, the worst season of the year, and it is seen that on 4 Mc/s the required field intensity is approximately one-sixth, and on 8 Mc/s one-twentieth of that on the medium waves. The figure of 3.6 millivolts/metre for a frequency somewhere near the middle of the medium-wave band may be compared with that of 1.0 millivolt/metre, the minimum field intensity for broadcast reception in a quiet country district in the British Isles. But it must be stressed that both these figures—3.6 mV/m. in the tropics and 1.0 mV/m. in this country—are for districts where there is no man-made noise, and in all the urban districts of the countries considered considerably higher field intensities are in fact required. In the tropics the man-made noise is usually particularly bad because of the common use of large numbers of electric fans, and these practically control the required field intensity on short waves in many districts. One reliable authority gives the following values of required field intensity in the presence of such man-made noise: 4 mV/m. on 2.3 Mc/s, 2 mV/m. on 4.6 Mc/s, and 1 mV/m. on 9.4 Mc/s and higher, when only 100 μV/m. was necessary in the absence of the noise.[2] So, the noise situation being a very variable one, we may continue to work with the figures given in the table, bearing in mind that they are for quiet districts only.

There is, of course, a diurnal variation in the radio noise intensity, the thunderstorm production being dependent upon the diurnal variation in temperature, and other meteorological effects. This variation in the noise intensity is such that a maximum occurs in the late afternoon and a minimum in the early morning, and it is of a considerable magnitude. There is not a *great* difference in the intensity of the noise, however, between noon and midnight local time, so we may take the above figures of required field intensity as applying roughly to the whole period between noon and midnight.

Range and Coverage. — The next step is to find out the maximum distance at which the required field intensities would be maintained on the various frequencies. We will ignore for the moment the question as to whether the ionisation of the refracting layer would be high enough to refract the frequencies we are considering, or whether they would penetrate through it. We will assume the former condition to apply.

On the frequencies 1 Mc/s and 2 Mc/s—within or near the medium-wave band—propagation would be by ground wave only during the day, and at night there would be sky wave propagation also. On the other frequencies considered only the sky wave would be of real importance, both by day and by night. The range for the required field intensities shown above for the various frequencies would depend upon a number of factors, chief of which are (a) the power radiated, (b) directivity of the aerial system, (c) ground absorption, (d) ionospheric absorption.

In order to arrive at some figures which will give an indication of the conditions to be met we must therefore make various assumptions. We will assume, in the first place, a radiated power of 50 kW and the use of a non-directive aerial system, it being remembered that we aim to give local all-round coverage. We need not here concern ourselves with the type of aerial which would be necessary for this purpose, but it ought to be mentioned that in



Idealised picture of a local short-wave broadcasting service, using F layer skywave transmission.

[2] All-India Radio.

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practice, its directivity in the vertical plane would be a matter of considerable importance. The ground absorption will depend, of course, upon the nature of the terrain, and will be no different in the tropics from that encountered in temperate zones, so we may consult the usual data for transmission over a good earth in a temperate zone in order to determine the distance range of the ground wave.

On those frequencies where the sky wave is made use of it is ionospheric absorption which will determine the range. This is more difficult to assess than the ground absorption, and little data are available. The ionospheric absorption occurs mainly in the lowest part of the ionosphere and is dependent upon the amount of ionisation in the absorbing region. This will be much greater in the tropics than in temperate regions, because in the tropics the sun is more directly overhead and its ionising rays are therefore stronger. It is evident that the ionisation will vary greatly with time of day, being greatest at midday and practically negligible during darkness, owing to the high recombination rate in the absorbing region. The ionospheric absorption in the tropics then will be negligible at night and no different from what it is in temperate zones, and between sunrise and sunset it will vary in amount, with the maximum occurring at noon. In order to determine the sky wave ranges then we will estimate the effect of ionospheric absorption at noon and at midnight only, in order to indicate the worst and the best conditions likely to be met.

Ionospheric absorption varies inversely, of course, with frequency, it being less on the higher frequencies because the rate of collision between the electrons and ions in the ionosphere—which are its intrinsic cause—depends upon the magnitude of their *motion* when acted upon by the radio wave, and this is less when the electric field of the wave reverses itself more frequently in a given time. The distance range will therefore increase markedly as the frequency is increased.

Taking all the above factors into consideration the following are the estimated ranges for the required field intensities on the different frequencies we are considering.

Thus, on 1 Mc/s and 2 Mc/s the ground wave only is of use during the day, and on 1 Mc/s (300 m) owing to the high field intensity required to overcome the noise, this only has a range of 50 miles. On 2 Mc/s (150 m) though the required field intensity is less, this is more than counteracted by the increased ground absorption, and so the distance range falls to only 38 miles. On 4 Mc/s (75 m) sky wave propagation is obtained and the distance range goes up to 220 miles, whilst on 8 Mc/s (37 m) it is further increased to 820 miles, because both the noise intensity and the ionospheric absorption are reduced.

Estimated distance range for required field intensity for 50 kW radiated

	1 Mc/s	2 Mc/s	4 Mc/s	8 Mc/s
Noon	50*miles	38* miles	220 miles	820 miles
Midnight	270	460	1,350	3,300

* Ground wave only.

At night the ionospheric absorption becomes of a very low value and so the distance range on all the frequencies is much enhanced, though it is, of course, still much smaller on the lower frequencies than the higher, because of the greater field intensity required to overcome the noise on the lower frequencies.

The net result of our investigations, so far, is to show that (a) the higher the frequency the better will the coverage be, *provided that the wave does not penetrate the ionosphere*, and (b) that at the time of day when the ionospheric absorption is highest *economical* coverage can only be obtained on frequencies higher than 4 Mc/s, though at night it could probably be obtained on frequencies nearly down to 2 Mc/s. (For reasons mentioned earlier on, the *degree* of coverage aimed at is usually less in tropical than in more highly developed countries, and it has here been considered that *economical* coverage is attained if the transmitter has a range of 500 miles. It should be noted also that the ionospheric absorption varies markedly over the day, and that the ranges would be greater over most of the day than those shown for noon.)

Conditions for Refraction.—But it is evident that it will be no good using 4 Mc/s or 8 Mc/s at any time of day if the ionosphere refracting layer permits it to penetrate, even at the highest elevation angles, for the production of a skip zone surrounding the transmitter must be avoided. So we had better examine the conditions in order to see what is the *highest* frequency which will be refracted.

It is assumed that the wave will be refracted at the F or F_2 layer. If the wave is to be returned at all distances from the transmitter outwards it is necessary to use a wave which is below the critical frequency of the refracting layer at any time of day. Then it will be returned at vertical incidence and at all greater angles of incidence, and the earth will be illuminated by the downcoming rays from the transmitter outwards. The critical frequency varies very much, of course, with time of day and season of year, but, as has already been said, because the ionising rays of the sun are stronger in the tropics than in temperate zones, the critical frequency will be generally higher there. The use of higher frequencies than for the same purpose in a temperate zone will therefore be possible.

The following table gives approximately the estimated lowest

Estimated lowest critical frequencies for tropical zone, F_1 F_2 layer

	Midnight Mc/s	Diurnal Minimum Mc/s	Noon Mc/s	Sunset Mc/s
June	4.0	3.0	6.5	6.0
March and Sept. ...	4.0	3.5	8.5	7.5
December ...	3.5	2.5	7.5	5.0

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critical frequencies of the F and F_2 layers throughout the geographical tropical zones for four significant times of day and for four seasons of the year.

It is seen that the critical frequency varies in a rather complicated way with the seasons, and this is to be expected because we are considering an area which extends into opposite hemispheres. It should be noted, however, that although the seasonal variations are in the opposite sense in the two hemispheres the ionospheric variations are not necessarily so, being somewhat more complicated than we can deal with here. However, the figures given are thought to be valid for the whole of the geographical tropics, and it is seen that highest daytime frequencies prevail at the equinoxes and lowest night-time ones during December.

As has already been said, it is advantageous for several reasons to make use of the highest frequencies possible, but obviously it would not be advisable in a *local* broadcasting service to make too frequent changes in the working frequency, either diurnally or seasonally.

The table indicates, in the first place, that 2.5 Mc/s (120-metre band) is hardly ever necessary—it is certainly the lowest frequency ever necessary—for night-time use. It is to be noted that a *local* broadcasting service is not often required to function between midnight and sunrise local time. 3.5 Mc/s (90-metre band) is shown to be a very useful and even necessary frequency for use during local evening hours up to midnight—but 5.0 Mc/s (60-metre band) is too high for night-time use, and, we see, somewhat too low for the daytime. It might, of course, be of considerable use as an intermediate frequency for use during certain periods of the day, as, for example, around sunset at certain seasons. But it is evident that over considerable periods of the day a higher frequency than this should be employed, and, if it is to be of some use at all seasons of the year, this would appear to be in the region of 6.5 Mc/s (46 metres). This would have a considerable period of utility all the year round ranging from 6 to 11 hours daily, according to the season. It might be thought that the use of a frequency so high as 6.5 Mc/s for local broadcasting would lead to unwanted distance ranges, and thus to interference with other services operating on or near the same frequency band outside the tropics. There are two ways in which this could be prevented: (a) by restricting the use of 6.5 Mc/s to certain hours when the ionospheric absorption is relatively high and thus the range is relatively small and the wave is not likely to reach to distances where it can cause interference; (b) by adjusting the elevation angle of the aerial system so that low-angle radiation does not take place. This latter step is in any case necessary if a *local* area is to be served, i.e., the energy must be radiated at relatively great elevation angles, and that radiated at low angles would be a waste of power so far as service within the area was concerned.

There remains the possibility of energy reaching to great distances by *multiple* hops at the greater angles, but if the wave is only used when high ionospheric absorption necessitates its use this danger should not be great.

It seems, therefore, that in order to provide efficient service in tropical countries at all seasons and necessary times of day the use of the two higher of the tropical broadcasting bands at present in use is desirable, together with that of an additional band at about 6.5 Mc/s. The utility of these three bands would seem to be somewhat as is indicated in the above table.

Utility of bands

	3.5 Mc/s	5.0 Mc/s	6.5 Mc/s
Most important period of use.	Early morning and late night according to season.	Late afternoon and early evening according to season.	Period ranging from 0900 to 1500 in December to 0800 to 1900 at equinox.
Approximate ranges at time of use.	750 miles.	600 miles.	700 miles.

The above figures for distance are, of course, very approximate. The ionospheric absorption varies markedly throughout the indicated periods of use and the ranges vary accordingly. In the afternoon, for example, when 5.0 Mc/s is of use there is still appreciable absorption, whereas after dark, when 3.5 Mc/s is of most use, it is almost negligible.

The figures do indicate, however, that economical coverage of tropical areas could be accomplished by the use of these frequencies. Even where there is a considerable amount of man-made noise the field intensities, at least at distances somewhat less than those shown above, should be adequate for satisfactory reception. Incidentally, to put down the same field at 500 miles as it is estimated would be put down by a 50 kW transmitter on 6.5 Mc/s at 700 miles, a transmitter operating at the middle of the medium-wave band would have to radiate about 53,000 kW.

There remains the possibility of covering an area by making use, not of the F layer of the ionosphere, but of the E layer instead. This could be done during the daytime only and by the use of a relatively low frequency. However, this would introduce considerable complications into the aerial arrangements, for a different angle of elevation would have to be employed when using the E than when using the F. Furthermore, as the ionospheric absorption decreases markedly with increasing frequency there does not seem much point in using a relatively low frequency in order to secure reflection from the E, when a higher one may be relied upon to be reliably returned from the F.

GEAR FOR AMATEURS

IT is expected that amateur transmitters will soon need a large quantity of components, accessories and other apparatus; to help the industry to meet this demand, the Radio Society of Great Britain (Little Russell Street, London, W.C.1) has issued a list of what is likely to be needed. Copies are available to manufacturers.

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